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To: Mr. William F. Caton, Acting Secretary

Date: April 19, 1996

From: Jennifer M. Gilsenan

Re: CC Docket No. 92-297

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Feasibility of Sharing between NASA Space Systems and LMDS systems near 27 GHz

1. Introduction

The National Aeronautics and Space Administration has been asked to examine the sharing feasibility between NASA space services and Local Multipoint Distribution Services below 27.5 GHz. It should be noted that, because of the need to complete this report very quickly, there has been insufficient time to permit a proper review by Goddard Spaceflight Center or Johnson Space Center, the relevant expert NASA Centers. Comments from those Centers may be anticipated in the near future. This report addresses this complex sharing situation, given the system characteristics provided by the LMDS proponents, with the following caveats:

- It was not possible to coordinate the analysis with other space agencies, particularly the European Space Agency (ESA) and the National Space Development Agency of Japan (NASDA), both of which are implementing communications systems that will rely heavily on this frequency band.

- It does not cover specifically planned Department of Defense systems which would operate in this band.

- It does not address the needs of commercial Earth Exploration-satellite systems for high capacity downlinks.

NASA will operate three types of space systems in the band below 27.5 GHz. These are:

- The Tracking and Data Relay Satellite System (TDRS)

- The Proximity Operations Communications System (POCS)

- Earth Exploration Satellite (EES) Service downlinks for NASA satellites

Sharing between LMDS and other space systems operating in the 27.5 - 29.5 GHz band have been studied intensively within the negotiated rulemaking process. The sharing situation between LMDS and EES downlink Earth stations is directly analogous to the sharing situations studied in the negotiated rulemaking, although interference in this case would occur in the EES Earth station rather than the LMDS receivers.

The interference situation between LMDS and TDRS is very different from the LMDS/FSS or LMDS/feeder link situations. Although TDRS systems would not have any Earth stations in this band, the antenna beam of the geostationary TDRS satellite will, of necessity, intersect the Earth at an elevation angle of 0°, creating a direct main beam-to-main beam interference situation with LMDS transmitters.

This report also does not address interference into the LMDS systems. The space systems operating in this band can emit at the levels equal to the PFD limits (RR 2578) for all angles of arrival, including 0°. It is not known if the LMDS proponents have analyzed the effect of this interference.

2. Existing ITU-R documentation

The Radio Regulations contain a limit on the EIRP spectral density emitted by terrestrial systems operating in the 25.25 - 27.5 GHz band (RR2504A), adopted by WARC-92 based on analyses of fixed point-to-point systems. The WARC also asked the then CCIR to study the issue and make a recommendation.

Joint ad hoc 7B/9D was formed to address this issue. Currently within the ad hoc, there is a Preliminary Draft New Recommendation (PDNR) which sets forth EIRP density limits for fixed service stations operating in this band. The recommendation is still under consideration. The basis for the recommendation is analyses of interference into TDRS systems from point-to-point and low density point-to-multipoint systems, as described in the Fixed Service Steering group which provided information on terrestrial systems planned for the band. The PDNR does *not* address high density point-to-multipoint systems such as LMDS

Canada submitted a document to WP 9D concerning its low-density LMCS system sharing with data relay satellites. This document was noted by WP 9D and sent for consideration to Joint Ad Hoc 7B-9D.

3. Space systems operational characteristics

Unless otherwise stated, the space system characteristics given in this section are used in the interference analyses. The three different types of NASA space systems are the Tracking and Data Relay Satellite System (TDRS), the Proximity Operations Communications System (POCS) and NASA Earth Exploration Satellite (EES) service direct ground links.

3.1 TDRS systems

NASA's TDRS system has been used to relay data between user satellites and Earth using S-band and Ku-band frequencies since 1983. The TDRS H, I & J satellites, which are currently under contract and planned for launch starting in 1999, will provide these services in the 25.25 - 27.5 GHz band, as well as in the lower frequency bands, thereby increasing capacity and improving service. The use of 25.25 - 27.5 GHz band is particularly important because of ITU-R Resolution 711 which resolves "that it is desirable to review the present and planned use of the frequency bands 2 025 - 2 110 MHz and 2 200 - 2 290 MHz, with the intent, where practicable, of assigning frequencies to space missions in bands above 20 GHz and possibly reducing the allocations to the space services in the 2 GHz band." Also, the NTIA is encouraging NASA to move data relay satellites out of the Ku-band into the Ka-band, so as to relieve interference situations in that band.

The TDRS 25.25 - 27.5 GHz channels are designed to support data rates ranging from 1 kbps to 800 Mbps. The 800 Mbps data rate is accommodated in a 650 MHz bandwidth and is required to transmit wide-band sensor data. Lower data rates will use bandwidths commensurate with the data rate. The need to support several of these wide band channels within a given orbital area is foreseen.

The hypothetical reference circuit for data relay satellite systems is given in Rec. ITU-R SA. 1018. Characteristics and interference criteria for data relay satellite systems is given in Rec. ITU-R SA. 1155. For the purposes of this analysis, the characteristics of the TDRS receiving system are as follows:

TDRS receive antenna gain	58.0 dBi
TDRS system noise temperature, evaluated at the satellite receiver	-138.0 dBW in 1 MHz
TDRS interference criteria (I/N)	-148.0 dBW in 1 MHz

based on satellite orbital period

The -148.0 dBW in 1 MHz interference criteria given above is based on Rec. ITU-R SA.1155 which specifies a maximum aggregate interference level of -178 dBW/kHz not to be exceeded for more than 0.1% of the time. The TDRS mainbeam will be pointed at any given point near the Earth's limb for about 0.1% of the time, so that the Rec. ITU-R SA.1155 interference criteria would essentially permit one interferer to be pointed at the TDRS orbital location. Because a high density point-to-multipoint system can be expected to have many transmitting antennas pointed at the TDRS, and so the maximum levels of interference would exist for more than 0.1% of the time.

3.2 Proximity Operations Communication System

Future demands on Low Earth orbit communications between space vehicles in close proximity will require reliable, bandwidth efficient links with the capability of high data transmissions. Types of data to be transmitted will range from simple telemetry to color telerobotics video (data rates greater than 100 Mbps). In addition, ESA has stated a requirement for 4 simultaneous channels of 60 Mbps. This type of proximity operations communications system may also have applications to low orbit inter-vehicle communications in future planetary missions. The Proximity Operations Communication System (POCS) has completed Stage 1 review and is being readied for Stage 2 review for operation in the 25.25 - 25.55 GHz and 27.225 - 27.5 GHz bands.

POCS will operate on satellites at altitudes from 280 km to 500 km with inclinations from 28.5 - 57 degrees. The POCS receiving system will utilize a 32.5 dBi antenna and have a system noise temperature of 773 K. The appropriate interference criteria for the POCS system can be found in Rec. ITU-R SA.-609 and is an I/N ratio of -6 dB.

3.3 Earth exploration-satellite downlinks

WARC-92 recognized the need for wide band Earth Exploration-Satellite Service (EES) downlinks near 26 GHz and made a secondary allocation to the service in the band. The band 8,025 - 8,400 MHz, which is currently used by the EES, is becoming congested by users of all of the allocated space services in that band. Advances in technology are providing higher resolution instruments which in turn require ever larger bandwidths to download their data from the spacecraft. For these reasons, a wide band allocation near 26 GHz is essential.

WRC-95, in response to proposals by the United States and India, decided that this issue should be considered further and placed it on the agenda for WRC-97. Agenda item 1.9.4.2 addresses consideration of an allocation to the (EES) near 26 GHz to provide direct downlinks of EES data to Earth.

EES use of the band will consist of satellites in low Earth orbits, typically less than 1,000 km altitude, and geostationary satellites, transmitting directly to Earth stations. Typical sites for Earth stations will be universities and private meteorological organizations in urban areas.

4. LMDS characteristics

Interference into TDRS systems due to emissions from LMDS systems will be evaluated on two bases. The first involves the specific characteristics of LMDS systems as given in section 4.1. The second involves evaluating interference based on the EIRP limit curves contained in Appendix B to the Third NPRM.

4.1 Characteristics used in the analysis

Unless otherwise stated with respect to a specific analysis, the LMDS characteristics used in this analysis are as given in Figure 4-1. These characteristics were selected from the range of values provided. Antenna gain patterns, developed from the information provided, are given in Figures 4-2 and 4-3.

The EIRP/MHz values listed in Figure 4-1 were provided for this study by the LMDS proponents. With one exception, all LMDS signals were digital and no peaking or interleave factor was assumed. CVUS for their hub transmissions specified a wide range of values from 7 dB(W/20 MHz) channel in their existing TV/FM installation in New York to the 25 dB(W/MHz) they have proposed to the FCC for both hub and subscriber transmissions. The existing TV/FM system is estimated to produce a 1 dB(W/MHz) EIRP taking into account a 10 dB peaking factor and a -3 dB interleave factor. The upper and lower bounds of this 24 dB EIRP range were evaluated.

Hub antennas for CVUS and TI are omni-directional in azimuth and were modeled using the equations in Figure 4.2 with one co-frequency signal per hub. The main beam was depressed below the horizon by the value supplied by the proponents (Figure 4-1). Where a range of values was provided, the minimum value was used.

The Endgate hub consists of 36 azimuthal sectors. The HP hub consists of 4 azimuthal sectors. They were modeled as a single toroidal antennas, omnidirectional in azimuth radiating one co-frequency signal per hub under the assumption that signal from one sector would be the dominant interferer in any azimuthal direction.

Subscriber antennas for all proponents exhibited high-gain, circular beams. In general, a large number of LMDS cells are within a spacecraft receiving beam footprint and subject its receiver to the "average" of LMDS subscribers located at random within their respective cell areas. Subscribers were modeled by an "azimuth-averaged" antenna pattern in much the same manner used in the Canadian Report.

A cell area was uniformly populated with subscriber antennas pointing at a hub receiver at 30 meters altitude. At a given reference elevation angle, the necessary pointing angles and resultant subscriber antenna gains, and distance from the hub receiver were calculated for each subscriber. It was assumed that the EIRP of each subscriber was proportional to the square of its distance from the hub receiver and that its elevation angle increased near the hub (flat Earth approximation). The resultant EIRP at the given reference elevation angle was summed over all subscribers within the cell and the result divided by the number of subscribers to arrive at an "average" subscriber EIRP for an LMDS cell. The process was repeated over the range of elevations from 0° to 90°. The result was an "average" subscriber pattern, omnidirectional in azimuth, varying only in elevation valid for the case of 1 co-frequency subscriber per LMDS cell. LMDS sectored-hub systems may accommodate more than one co-frequency subscriber per cell - this case was modeled by increasing the model EIRP in proportion to the maximum number of active subscribers.

	CVUS Hub	CVUS Sub	TI Hub	TI Sub	END Hub	END Sub	HP Hub	HP Sub
EIRPo (dBW/MHz)	25.0[4]	25.0[4]	7.0	17.0	-3.3	-9.7	-8.0	18.0[1]
Cell Radii (km)	see Figure 5-2							
Average Height of Hub above ground (m)	30	30	30	30	30	30	30	30
Elevation of Hub antenna main beam (° from horizon)	-1		-2		-1.5		-0.3	
Transmitter power as a function of subscriber-to-hub distance (dB)		20 log(d)		20 log(d)		20 log(d)		20 log(d)
Peaking factors (dB)[2]	10	0	0	0	0	0	0	0
Interleave factors (dB)	-3	-3						
Maximum percent of area populated by LMDS cells for satellite beams of size:								
144,000					2 - 30		5 - 10	
40,000					10 - 40		10 - 35	
7,000					25 - 85		30 - 70	
Maximum subscriber pointing angle above the horizontal (°)		5		15		15		5 7
Maximum antenna gain (dBi	12	31	15	34	31[3]	40[3]	15	35
Number of Hub antenna sectors	1		1		36		6	

Notes:

1 18 dBW/MHz for clear sky $EIRP_0$ was assumed based on the 22 dBW/MHz $EIRP_0$ for rain conditions minus 1 dB/km * 4 km cell radius

2 Applicable when the victim bandwidth is much narrower than an FM-TV signal

3 40 dBi was provided in the data package, but 31 dBi is consistent with the beamwidths given

4 These values were provided by CVUS. In most of the following analyses, values of 1 and 10 dBW/MHz are used for the Hub and Subscriber $EIRP_0$. The 25 dBW/MHz is treated as a separate case.

Figure 4-1. LMDS characteristics provided

CVUS Hub in dB relative to mainbeam gain of 12 dB(i)	
$-3(\varnothing/3.27)^2$	$0 \le \varnothing < 10$ degrees
-28	$10 \le \varnothing < 35.8$ degrees
$-0.34\varnothing$ -15.9	$35.8 \le \varnothing < 65$ degrees
-38	$65 \le \varnothing \le 90$ degrees
TI Hub in dB relative to mainbeam gain of 15 dB(i):	
$-3(\varnothing/3.98)^2$	$0 \le \varnothing < 8.9$ degrees
$6.18 - 2.38\varnothing$	$8.9 \le \varnothing < 11$ degrees
-20	$11 \le \varnothing < 25$ degrees
$-7.5 - 0.5\varnothing$	$25 \le \varnothing < 35$ degrees
-25	$35 \le \varnothing \le 90$ degrees
Endgate Hub in dB relative to mainbeam gain of 31 dB(i), 36 sectors:	
0	$0 \le \varnothing < 1$ degree
$-10 - 28 \log\varnothing$	$1 \le \varnothing \le 90$ degrees for a single sector
HP Hub in dB relative to mainbeam gain of 15 dB(i), 6 sectors:	
Sector Hub, Elevation Plane	
$-0.0885\varnothing^2$	$0 \le \varnothing < 10.63$ degrees
-10	$10.63 \le \varnothing < 17.5$ degrees
$26.53 - 29.39 \log\varnothing$	$17.5 \le \varnothing \le 90$ degrees for a single sector

Figure 4-2. Assumed Hub antenna patterns

All patterns are assumed to be circularly symmetrical	
CVUS Subscriber in dB relative to mainbeam gain of 31 dB(i):	
$-3(\varnothing/2)^2$	$0 \le \varnothing < 4.9$ degrees
-18	$4.9 \le \varnothing < 12$ degrees
-24	$12 \le \varnothing < 50$ degrees
-30	$50 \le \varnothing < 90$ degrees
$99.84 - 66.64 \log\varnothing$	$90 \le \varnothing \le 180$ degrees
TI Subscriber in dB relative to mainbeam gain of 34 dB(i):	
0	$0 \le \varnothing < 1$ degrees
$-3.2(\varnothing-1)$	$1 \le \varnothing < 6$ degrees
-16	$6 \le \varnothing < 14$ degrees
$180 - 14\varnothing$	$14 \le \varnothing < 15$ degrees
-30	$15 \le \varnothing \le 180$ degrees
Endgate Subscriber in dB relative to mainbeam gain of 40 dB(i):	
$-3(\varnothing/.985)^2$	$0 \le \varnothing < 3$ degrees
$-21-14.5 \log \varnothing$	$3 \le \varnothing \le 180$ degrees
HP Subscriber in dB relative to mainbeam gain of 35 dB(i)	
$-1.78\varnothing^2$	$0 \le \varnothing < 3.9$ degrees
-27	$3.9 \le \varnothing < 5$ degrees
$-5.1 - 31.33 \log\varnothing$	$5 \le \varnothing < 13$ degrees
-40	$13 \le \varnothing \le 180$ degrees

Figure 4-3. Assumed subscriber antenna patterns

4.2 Third NPRM EIRP limits

The Third NPRM with respect to LMDS in the 27.5 - 29.5 GHz frequency band provides a proposed EIRP limit on the aggregate power spectral density emitted by an LMDS, averaged over the LMDS system's BTA. For 0° elevation angles, the limits are as follows:

Climate Zone	EIRP Spectral Density (Clear Air) (dBW/MHz-km2)**
1	-23
2	-25
3,4,5	-26

These limits would be reduced (made more restrictive) for higher angles of elevation as follows:

Elevation Angle (a)	Relative EIRP Density (dBW/MHz-km2)
$0° \leq a \leq 4.0°$	$EIRP(a) = EIRP(0) + 20 \log (\sin \pi x)(1/\pi x)$ where $x = (a + 1)/7.5$
$4.0 < a \leq 7.7°$	$EIRP(a) = EIRP(0) - 3.85a + 7.7$
$a > 7.7°$	$EIRP(a) = EIRP(0) - 22$

where a is the angle in degrees of elevation above horizon. EIRP(0°) is the hub EIRP area density at the horizon used in Section 21.1020. The nominal antenna pattern will be used for elevation angles between 0° and 8°, and average levels will be used for angles beyond 8°, where average levels will be calculated by sampling the antenna patterns in each 1° interval between 8° and 90°, dividing by 83.

The Third NPRM applies these limits to hub emissions only. An analysis by Hewlett-Packard ("Analysis of CPE Tx's Fit to Proposed Rules, 21.1020 & 21.1021 per 3rd NPRM for 28 GHz using Proposed Rules for CPE Tx's in 150 MHz Band") indicated that these limits could also be met by the subscriber emissions. This report will use these limits to analyze interference from both hubs and subscribers.

5. Impact of the modeled LMDS systems on a TDRS

5.1 Effects of single, high powered LMDS emitters on a TDRS

As an initial step in the analysis, the impact of an individual LMDS transmitter pointed at a TDRS receiver was investigated. Table 5-1 presents a calculation of the interference received by a TDRS from each Hub or subscriber, assuming that the TDRS is visible at an elevation angle of 3°. The subscribers are assumed to have an antenna elevation of 1°.

As can be seen in the figure, a single CVUS Hub, CVUS Subscriber or HP subscriber operating at the maximum EIRP densities would produce interference in the TDRS. When the peaking factors are applied, the interference situation becomes much worse. The effect of multiple mainbeam hits would exacerbate the situation.

	CVUS Hub	CVUS Sub	CVUS Hub	CVUS Sub	TI Hub	TI Sub	END Hub	END Sub	HP Hub	HP Sub
EIRPo (dBW/MHz)	25.0	25.0	1.0	10.0	7.0	17.0	-3.3	-9.7	-8.0	18.0
Antenna elevation	-1.0	1.0	-1.0	1.0	-2.0	1.0	-1.0	1.0	-0.3	1.0
Elevation to TDRS	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
LMDS antenna discrimination (dB)	-4.5	-3.0	-4.5	-3.0	-4.7	-3.2	-26.9	-12.0	-3.1	0.0
Space loss to GSO	-213.5	-213.5	-213.5	-213.5	-213.5	-213.5	-213.5	-213.5	-213.5	-213.5
Atmospheric loss(dB)	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0
Polarization loss (dB)	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
TDRS Antenna gain	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0
Interference received (dBW/MHz	-144.0	-142.5	-168.0	-157.5	-162.2	-150.7	-194.6	-186.2	-175.5	-146.5
Interference criteria	-148.0	-148.0	-148.0	-148.0	-148.0	-148.0	-148.0	-148.0	-148.0	-148.0
Margin, no peaking (dB)	-4.0	-5.5	20.0	9.5	14.2	2.7	46.6	38.2	27.5	-1.5
Peaking factors	10.0									
Margin, with peaking	-14.0									

Figure 5-1. Impact of single LMDS emitters on a TDRS

5.2 Aggregate effect of LMDS models on a TDRS

The aggregate interference level in a TDRS receiver due to emissions from LMDS subscriber transmitters was evaluated based on the characteristics give in Figure 5-2.

The TDRS is a geostationary satellite whose high-gain receiving 0.15° beam tracks and receives signals from low-orbiting spacecraft. For the majority of the time, the TDRS receiving beam points toward the Earth.

A computer model points the TDRS 0.15° wide beam boresight to intersect the Earth at a specified angle of elevation. The TDRS 3 dB beam area intersection with the Earth is then fully populated with LMDS cells equally spaced using the cell radius from Figure 5-2. The necessary pointing angle, slant range, antenna gain, and clear-air atmospheric loss calculations (ITU-R PN.676-2) are made to determine the interfering power contribution from each cell. The aggregate interference power for 100% LMDS deployment is accumulated for a particular angle of elevation of the TDRS mainbeam boresight. The process is repeated for elevation angles from 0° to 90°.

For a 90° elevation angle, the TDRS beam intersection with the Earth is a circle of about 94 km diameter. A 100% "fill" of the beam area would be appropriate for high elevation angles.

For low elevation angles, the beam intersection takes on an elongated elliptical area of about 160 km wide and up to 1200 km long. A 33% "fill" of the beam area may be more appropriate for low elevation angles and is estimated by assuming LMDS interference levels are reduced by 10 log(33%/100%) = -4.8 dB.

Figure 5-2 lists the cases that were examined and the LMDS parameters used. With the exception of CVUS TV/FM hub transmissions, digital signals were specified by the proponents. It was found that the EIRP/MHz was essentially independent of the bandwidth and data rate of the several signals provided by each proponent.

The results for LMDS Hub transmissions were made on the basis of one co-channel signal per cell and are shown on Figure 5-3. The curves correspond to the labeled rain zone areas (1, 2, 3-5) from Table 5-2, and are shown for 33% fill of the beam area.

For CVUS hubs, the top 3 curves are for an EIRP of 1 dB(W/MHz) matching their existing New York system for the 3 rain zones. The interference margin to TDRS is negative for elevation angles below 10°. The lower curve illustrates the disastrous effect of a 25 dB(W/MHz) EIRP.

The TI and HP systems both show negative margins for elevation angles below 10°.

Endgate hubs show a positive margin for all elevation angles.

The results for LMDS subscriber transmissions were made on the basis of one co-channel signal per cell and are shown on Figure 5-4. The curves correspond to the labeled rain zone areas (1, 2, 3-5) from Table 5-2, and are shown for 33% fill of the beam area.

The results for LMDS subscriber transmissions were made on the basis of one co-channel signal per cell and are shown on Figure 5-4. The curves correspond to the labeled rain zone areas (1, 2, 3-5) from Table 5-2, and are shown for 33% fill of the beam area.

CVUS subscribers show a small positive margin for the 10 dB(W/MHz) value used for the Canadian LMCS system and a negative margin for all elevation angles for the 25 dB(W/MHz) limit that CVUS has proposed to the FCC.

Endgate subscribers show a large positive margin on the basis of 1 subscriber per cell. However, their 36 sector hub with full frequency reuse allows a maximum of 36 subscriber transmissions per cell which would reduce the margins by 15.6 dB for the higher angles of elevation, (that is, away from the hub antenna mainbeam). The HP system shows positive margins for most conditions.

TI subscribers cause a negative margin at low elevation angles.

See Appendix A, Figures A-1 and A-2 used in deriving the interference margin plots shown in Figures 5-3 and 5-4. The margins in these figures are for a 33% fill of the satellite beam footprint area.

Case name	EIRP/MHz	Rain Zone	Cell Radius	Location
CV Sub 1	10.0	1	2.7	Miami
CV Sub 2	10.0	2	4.8	New York
CV Sub 3	10.0	3	9.5	San Francisco
CV Sub 1 - 25	25.0	1	2.7	Miami
END Sub 1	-9.7	1	4.5	Miami
END Sub 2	-9.7	2	7.6	New York
END Sub 3	-9.7~~0~~	3	15	San Francisco
HP Sub 1	18	1	1	Miami
HP Sub 2	18.0	2	4*	New York
HP Sub 3	18.0	3	4*	San Francisco
TI Sub 1	17.0	1	2.5	Miami
TI Sub 2	17.0	2	5	New York
TI Sub 3	17.0	3	5	San Francisco
CV Hub 1	1.0	1	2.7	Miami
CV Hub 2	1.0	2	4.8	New York
CV Hub 3	1.0	3	9.5	San Francisco
CV Hub 1 - 25	25	1	2.7	Miami
END Hub 1	-3.3	1	4.5	Miami
END Hub 2	-3.3	2	7.6	New York
END Hub 3	-3.3	3	15	San Francisco
HP Hub 1	-8.0	1	0.5	Miami
HP Hub 2	-8.0	2	4	New York
HP Hub 3	-8.0	3	4	San Francisco
TI Hub 1	7.0	1	2.5	Miami
TI Hub 2	7.0	2	5	New York
TI Hub 3	7.0	3	5	San Francisco

Note: Late information received from HP indicated that these values should be 2 km radii. This would reduce the margin for interference received from these links by 6 dB.

Figure 5-2. LMDS Hub and Subscriber cases

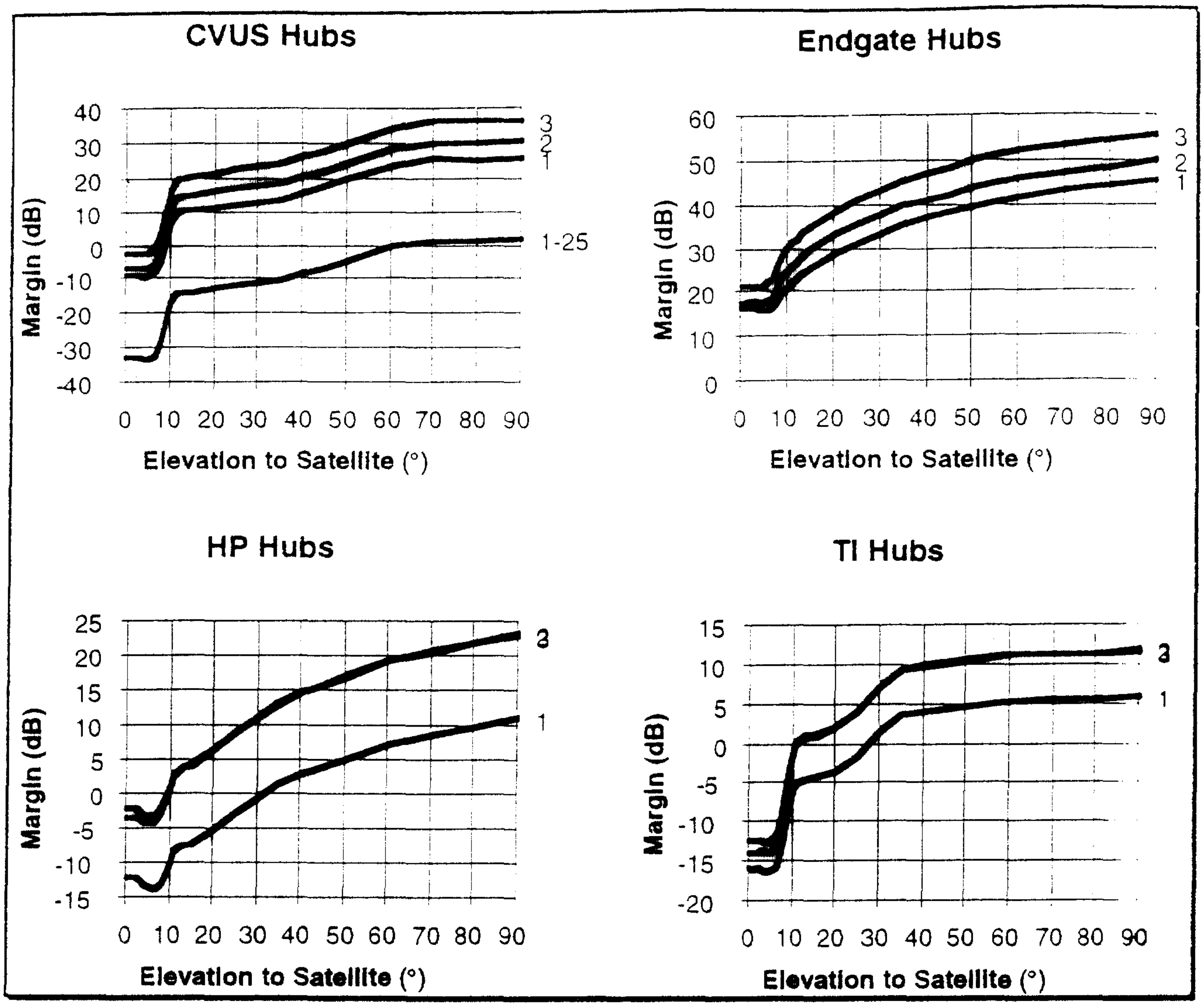

Figure 5-3. Interference from LMDS Hubs into a TDRS receiver as a function of elevation angle of the TDRS

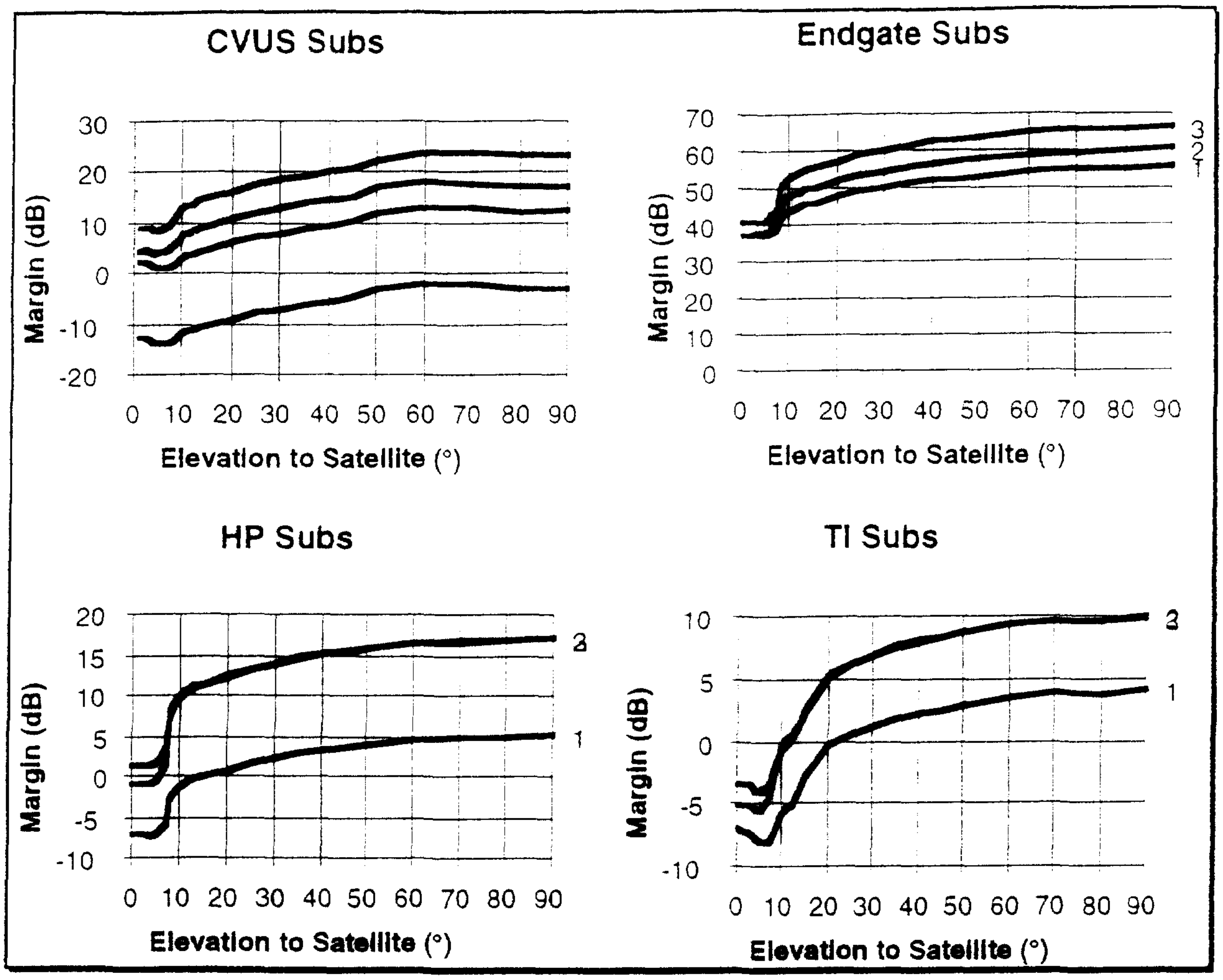

Figure 5-4. Interference from LMDS Subscribers into a TDRS receiver as a function of elevation angle of the TDRS

5.3 Impact of the proposed EIRP mask on TDRS

The Third NPRM proposed an EIRP limit on LMDS systems in the form of a maximum EIRP expressed in terms of dBW/MHz/km^2 (see §4.2). This EIRP mask was evaluated with respect to the levels of interference that would be received by a TDRS satellite receiver as a function of elevation angle from the LMDS emitters for Rain Zones 1, 2 & 3, with the results given in Figure 5-6.

As can be seen in the figure, unacceptable interference is produced at TDRS elevation angles from 0° to 7° in all three rain zones.

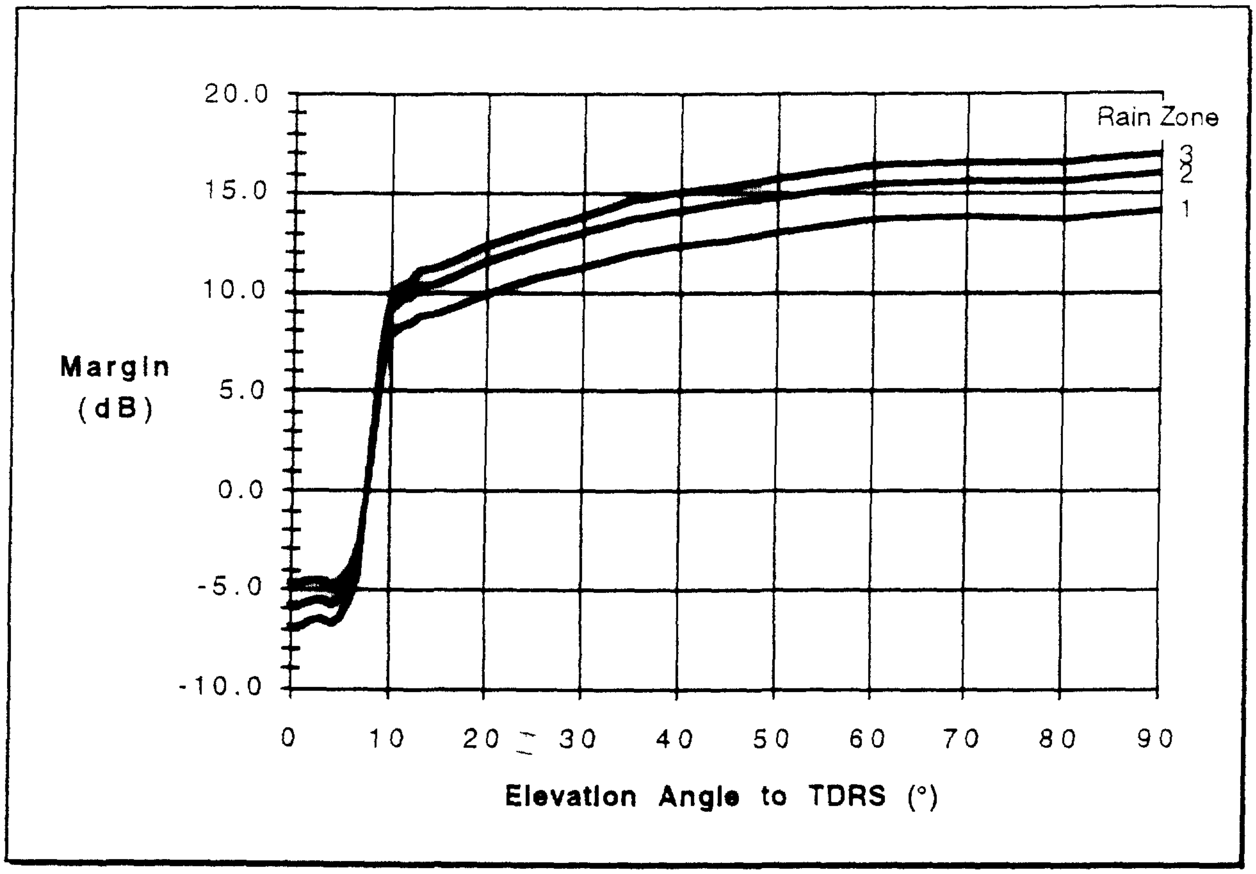

Figure 5-5. Interference impact of EIRP Mask on TDRS

5.4 Comparison to the Canadian study

A Canadian study (Doc. WP 9D-) of interference from LMCS, an LMDS-like system, found it was possible , in some conditions for LMCS to exceed the TDRS interference criteria and in other cases to exactly meet the criteria. Most situations modeled were acceptable. The LMCS system that was modeled, however, transmitted a relatively low power level system. A comparison between the LMCS systems and the CVUS and TI systems is given in the following table:

The Canadian System A parameters are essentially identical the CVUS 1 dB(W/MHz) hub case shown in Figure 5-3 and the CVUS subscriber case in Figure 5-4, differing primarily in the 1.9° hub down angle for the Canadian system (1° used in this study). The LMCS "B" parameters, which were originally considered to represent a TI-like system, actually are quite different and produce significantly lower levels of interference than those calculated using the parameters provided by TI for this study.

A comparison of the Canadian results to an analysis using the approach given in §5.2 of this report but using similar parameters to the Canadian report, yielded results that matched within 1-2 dB.

	Canadian LMCS System A Hub	CVUS Hub	Canadian LMCS System B Hub	TI Hub
EIRP/MHz	1	1	-11	7
Cell Radius, km	4.9	4.8	5.5	5
Hub down angle, deg	-1.9	-1	-2.3	-2
	Canadian LMCS System A Sub	CVUS Sub	Canadian LMCS System B Sub	TI Sub
EIRP/MHz	10	10	8.8	17
Cell Radius	4.9	4.8	5.5	5

Figure 5-6. Comparison of Canadian LMCS and US systems

6. Impact of modeled LMDS systems on Proximity Operations receivers

6.1 Effects of single, high powered LMDS emitters

As an initial step in the analysis of interference into the POCS receivers, the impact of a single LMDS transmitter pointed directly at the POCS was investigated. Figure 6-1 presents a calculation of the interference power received, assuming that the LMDS subscriber has an antenna elevation angle of 1° and the POCS is at an altitude of 280 km. The elevation of the POCS from the LMDS transmitter was assumed to be 3 ° (1° in the case of the HP Subscriber).

As can be seen in the table, individual CVUS Hub transmitters, exceed the interference criteria when peaking is considered, and approximately equal the criteria without peaking.

	CVUS Hub	CVUS Sub	CVUS Hub	CVUS Sub	TI Hub	TI Sub	END Hub	END Sub	HP Hub	HP Sub
EIRPo (dBW/MHz)	25.0	25.0	1.0	10.0	7.0	17.0	-3.3	-9.7	-8.0	18.0
Antenna elevation	-1.0	1.0	-1.0	1.0	-2.0	1.0	-1.0	1.0	-0.3	1.0
Elevation to POCS	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.0
LMDS antenna discrimination (dB)	-4.5	-3.0	-4.5	-3.0	-4.7	-3.2	-26.9	-12.0	-3.1	0.0
Space loss to POCS	-185.2	-185.2	-185.2	-185.2	-185.2	-185.2	-185.2	-185.2	-185.2	-186.7
Atmospheric loss(dB)	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-12.0
Polarization loss (dB)	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
POCS Antenna gain (dBi)	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5
Interference received (dBW/MHz	-141.2	-139.7	-165.2	-156.2	-159.4	-147.9	-191.8	-183.4	-172.7	-151.2
Interference criteria	-139.7	-139.7	-139.7	-139.7	-139.7	-139.7	-139.7	-139.7	-139.7	-139.7
Margin, no peaking (dB)	1.5	0.0	25.5	16.5	19.7	8.2	52.1	43.7	33.0	11.5
Peaking factors	10.0									
Margin, with peaking	-8.5									

Figure 6-1. Impact of a single LMDS transmitter on a POCS receiver

6.2 Aggregate effect of LMDS Hubs on a POCS

The POCS receives short range communications within the immediate vicinity of a space station assumed to be at a 350 km altitude. The receiving antenna 5.9° wide mainbeam may point in any direction, including toward the Earth. The computer model points the POCS 5.9° wide beam boresight to intersect the Earth at a specified angle of elevation. The POCS 3 dB beam area intersection with the Earth is then fully populated with LMDS cells equally spaced using the cell radius from Figure 5-2. The necessary pointing angle, slant range, antenna gain, and clear-air atmospheric loss calculations (ITU-R PN.676-2) are made to determine the interfering power contribution from each cell. The aggregate interference power for 100% LMDS deployment is accumulated for a particular angle of elevation of the POCS mainbeam boresight. The process is repeated for elevation angles from 0° to 90°.

For a 90° elevation angle, the POCS beam intersection with the Earth is a circle of about 36 km diameter. A 100% "fill" of the beam area would be appropriate for high elevation angles.

For low elevation angles, the beam intersection takes on an elongated elliptical area of about 160 km wide and up to 1100 km long. A 33% "fill" of the beam area may be more appropriate for low elevation angles and is estimated by assuming LMDS interference levels are reduced by 10 log(33%/100%) = -4.8 dB.

The results for LMDS Hub transmissions were made on the basis of one co-channel signal per cell and are shown on Figure 6-2. The curves correspond to the labeled rain zone areas (1, 2, 3-5) from Table 5-2 and are shown for 33% fill of beam area.

See Appendix A, Figures A-3 and A-4 used in deriving the interference margin plots shown in Figures 6-2 and 6-3. The margins in the figures are for a 33% fill of the satellite beam footprint area.

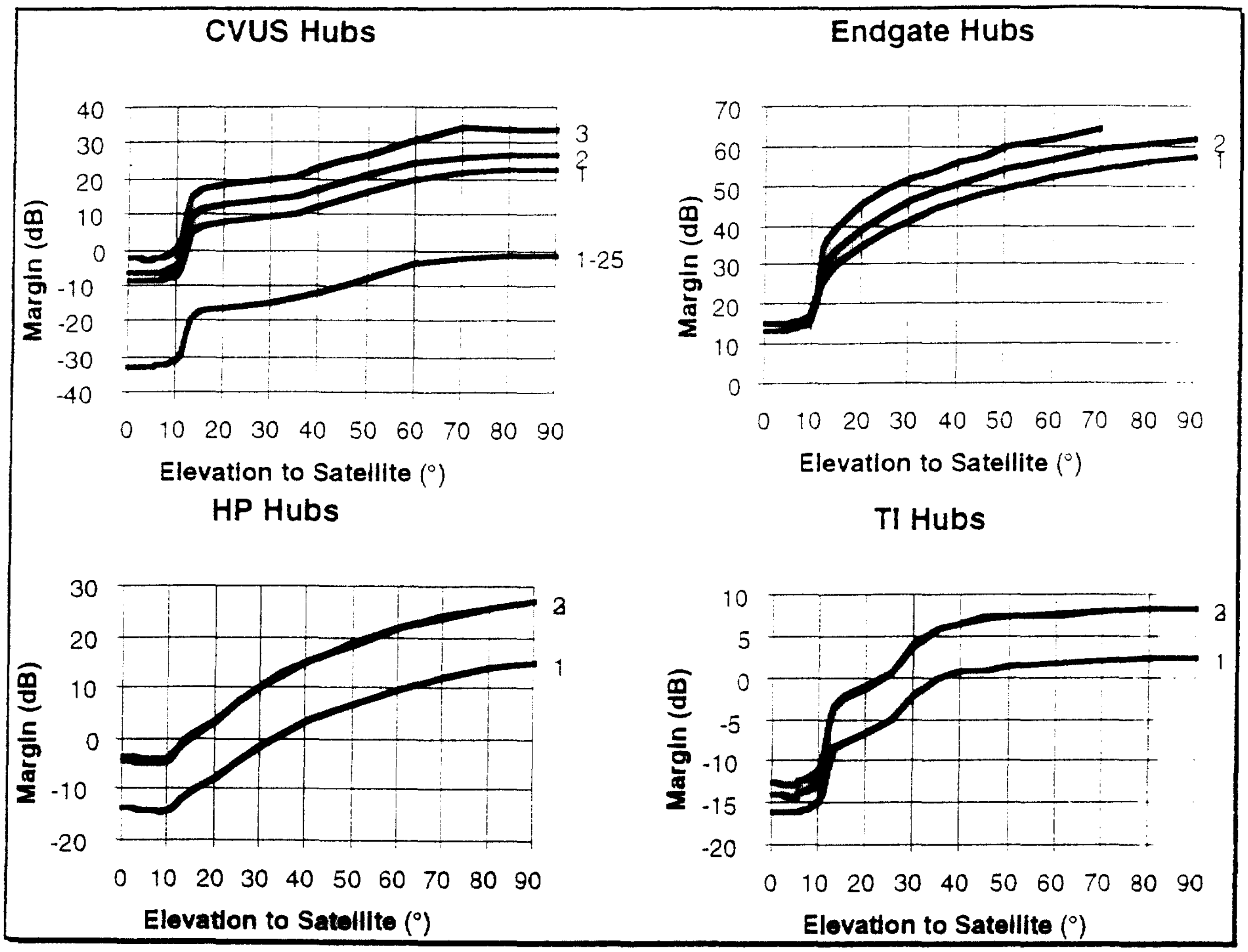

Figure 6-2. Hub to POCS interference as a function of elevation angle to the POCS

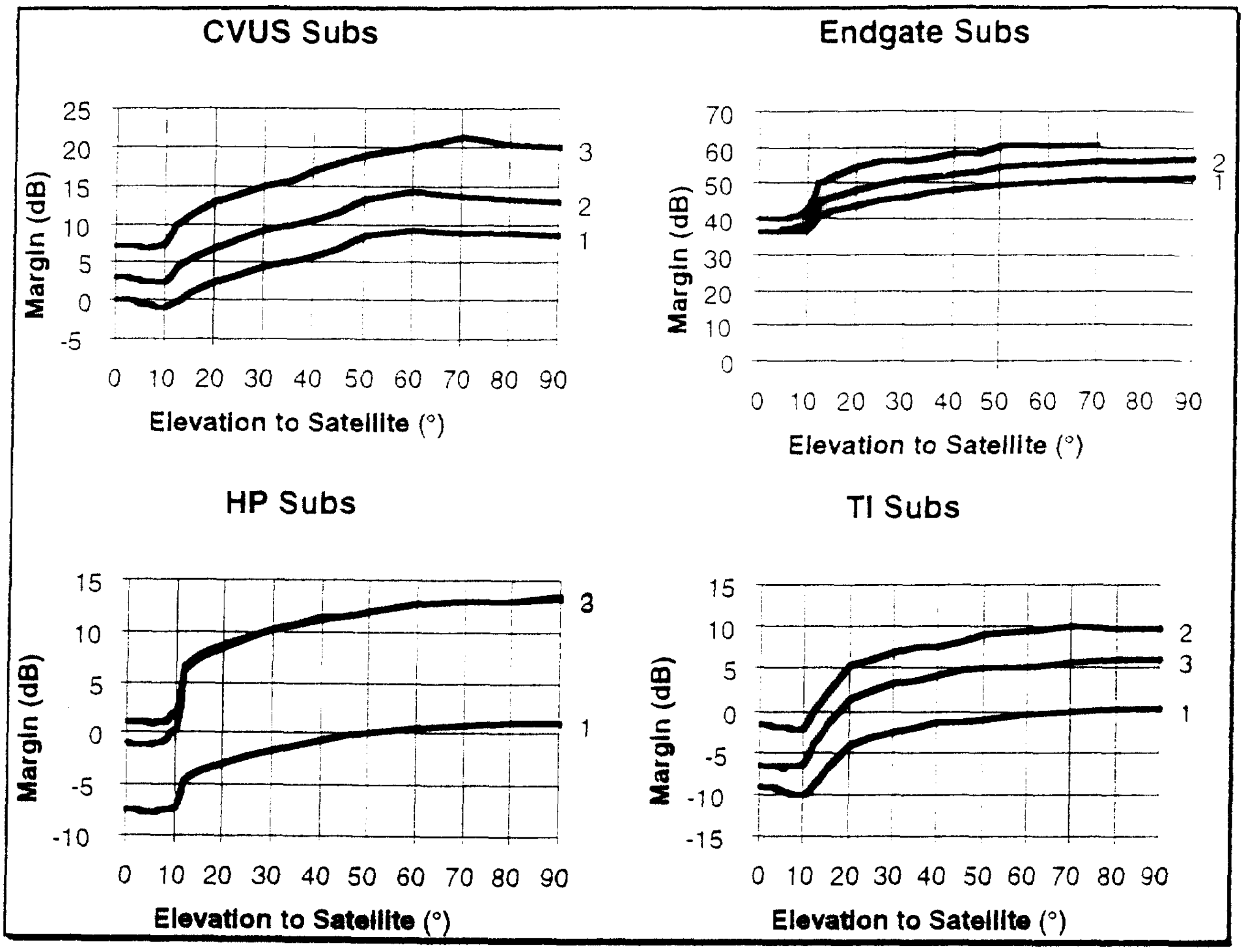

Figure 6-3. Graph of Subscriber to POCS interference as a function of elevation angle to the POCS

6.3 Aggregate Interference Effect of LMDS on POCS for Selected Metropolitan Areas

To further understand the effect of LMDS aggregate interference on the POCS space system, a MATLAB computer simulation program was developed to perform Monte Carlo simulations of LMDS interference originating from systems in specific metropolitan statistical areas (MSAs) such as New York and Miami. A description of the simulation program and the assumptions used in the analyses are given in Appendix B.

Using the simulation program, I/N margins were calculated for various beam elevation angles (i.e. beam footprint sizes) and LMDS coverage of the New York (rain zone 2) and Miami (rain zone 1) MSAs. For reference, beam footprint sizes and MSA areas used in the analyses are as follows:

Beam Boresight Elevation Angle (deg)	3 dB Beam Footprint Size @ 350 km;5.9° HPBW(km^2)
0°	141540
5°	151300
15°	39900
20°	19587
30°	7212
40°	3612
New York MSA Area	19825
Miami MSA Area	8196

Figure 6-4 shows the I/N margins at the POCS receiver resulting from CVUS subscribers operating at a T1 data rate and maximum EIRP level of 10 dBW. Curves are shown for various LMDS coverage "effective areas" where the effective area is defined to be that area in the beam footprint occupied by LMDS cells. The number of LMDS cells is found by dividing the effective area by the LMDS cell area. The concept of effective area is used to take into account the fact that beam footprints (especially large ones that occur at low elevation angles) will typically not be completely saturated with LMDS cells. The figure reflects three different methods of computing effective area (see Appendix B for a detailed explanation of these methods). A brief description will be given here, since it is important in understanding the graphs. Refer to Figure 6-4.

1) curves labeled "100% beam fill" use option A and the effective area is simply the entire 3 dB beam footprint area (i.e. the entire footprint is assumed to be populated with LMDS cells).

Hence, these generally give the lowest margins especially at low elevation angles where the footprints are large. Note that the (100% Beam fill RZ 1) curve in Figure 6-4 is worse than that for RZ 2 due to the smaller cell sizes in RZ 1 and hence larger number of cells in the footprint.

2) curves labeled "New York MSA only" or "Miami MSA only" use option B in which the effective area is taken to be the entire MSA area ***as long as the beam footprint is larger than the MSA.*** The rest of the footprint is assumed to be ***completely empty*** of LMDS cells. ***If the beam footprint, on the other hand, is smaller than the MSA itself, the effective area is taken to be equal to the beam area even if a 100% MSA coverage is specified.*** This typically happens at higher elevation angles. For example, the New York MSA is about 19800 km^2 in area. At 20° elevation, the beam footprint is about 19600 km^2 in area. Hence, at 20° elevation, the effective area is taken to be the footprint area of 19600 km^2. At angles above 20°, the effective areas for the 100% RZ2, NY only, and NY+33% curves are therefore simply the footprint area itself which is why they nearly overlap one another. The same effect occurs for the Miami curves (100% beam fill RZ 1, Miami only, Miami + 33%) at 30° elevation where the footprint size is 7200 km^2 and the Miami MSA area is 8200 km^2.

3) curves labeled "NY MSA + 33%" and "Miami MSA + 33%" use option C which is analogous to the Canadian approach for computing effective area. Again, if the beam footprint is larger than the MSA (which it is at low elevation angles), the effective area is taken to be the entire MSA ***+ 33% of the remaining footprint area outside the MSA.*** Like option B, however, if the beam footprint is smaller than the MSA, then the effective area is simply taken to be the beam footprint area itself. Again, this typically occurs at the higher elevation angles where the footprints are smaller. Hence, at the higher elevation angles, the I/N margin values for a particular MSA will generally be the same for ***all three options*** as indicated in Figure 6-4 for the New York and Miami MSAs.

Figure 6-4 indicates that CV subscribers with 10 dBW EIRP produce margins that are generally positive in all cases except the 100% beam fill case in rain zone 1. Figure B-1 in Appendix B, however, shows that when the proposed CV EIRP level of 25 dBW/MHz is used for the T1 subscribers, negative margins result for all cases with some reaching -15 dB. In analyzing the T1 subscriber interference, 15 randomly located T1 interferes per cell was assumed based on a 14.7 MHz space receive bandwidth and 1 MHz T1 subscriber bandwidth. In some simulation runs, the effect of deliberately forcing one T1 interferer per cell into azimuth (not necessarily elevation) alignment with the satellite was examined. Figure B-2 in Appendix B shows this case. As seen from the 100% beam fill curve, the impact is apparent only at the lower elevation angles where there is about a 5 dB drop in margin.

Figure 6-5 shows the I/N margins resulting from CV hubs transmitting 20 MHz FM/TV signals at 7.0 dBW EIRP. Note that negative margins occur in the 0°-5° elevation range for the lower two curves. Both of these are for the NY MSA+ 33% effective area case. The hub scatter curve assumes signal reflections off the ground from the hub terminals which add to the interference into the space receiver. The 10 dB peaking curve assumes a 1 MHz space system receive bandwidth which is being interfered with by the wideband 20 MHz FM/TV signals. Under these conditions of a narrowband victim bandwidth, the shape of the FM signal power spectral density becomes important and a 10 dB factor to account for the non-flat spectrum is applied.

Figure B-3 in Appendix B shows the result of increasing the hub EIRP to 40 dBW based on the proposed CV EIRP density of 25 dBW/MHz. In this case, severe interference is experienced over all elevation angles with margins going down to as much as -30 dB.

Figures 6-6 and 6-7 show the results for HP hubs and HP T1 subscribers, respectively. The 60 Mbps hubs operating at 8 dBW EIRP are seen to cause unacceptable interference up to 25° elevation for all cases. The T1 subscribers are also seen to cause negative margins in some situations. In Figure 6-7, note in particular the curve for Miami MSA only where 1 km radius cells are specified. For this curve, negative margins occur even at relatively high elevation angles. For example, negative margins occur at 30° and 40° elevation where the footprint sizes (7212 km^2 and 3612 km^2) are smaller than the Miami MSA.

Figure 6-8 shows the results for TI subscribers operating at 3.3 Mbps (2.5 MHZ) and 40 Mbps (30 MHZ) in the Miami area where the TI cell size is 2.5 km. Again, the relatively small cell size and low discrimination of the subscriber antennas causes significant interference up to 40° elevation and beyond. The New York MSA cases shown in Figure B-4 in Appendix B also show significant negative margins, although to a lesser degree due to the larger 5 km cell size. Like the CV case, the effect of forcing one of the 5 (2.5 MHZ) TI subscribers per cell into azimuth alignment with the satellite was examined. Figure B-5 shows this case. For example, by comparing the Miami+33% (2.5 MHZ) curves in Figures 6-8 and B-5, it is seen that forcing one interferer per cell into alignment causes about a 9 dB drop in margin.

Finally Figure 6-9 shows the interference due to the TI 200 Mbps (60 MHZ) hubs operating at 25 dBW EIRP in both the New York (5 km cells) and Miami (2.5 km cells) areas. For all four cases, severe interference is produced at the proximity operations space receiver over a broad elevation angle range. Interference from the lower power 20 dBW (65 Mbps/40 MHZ) TI hubs is also excessive as shown in Figure B-6 of Appendix B.

Because the ENDGATE LMDS system showed relatively high I/N margins even for 100% beam fill, plots for this system were not generated.

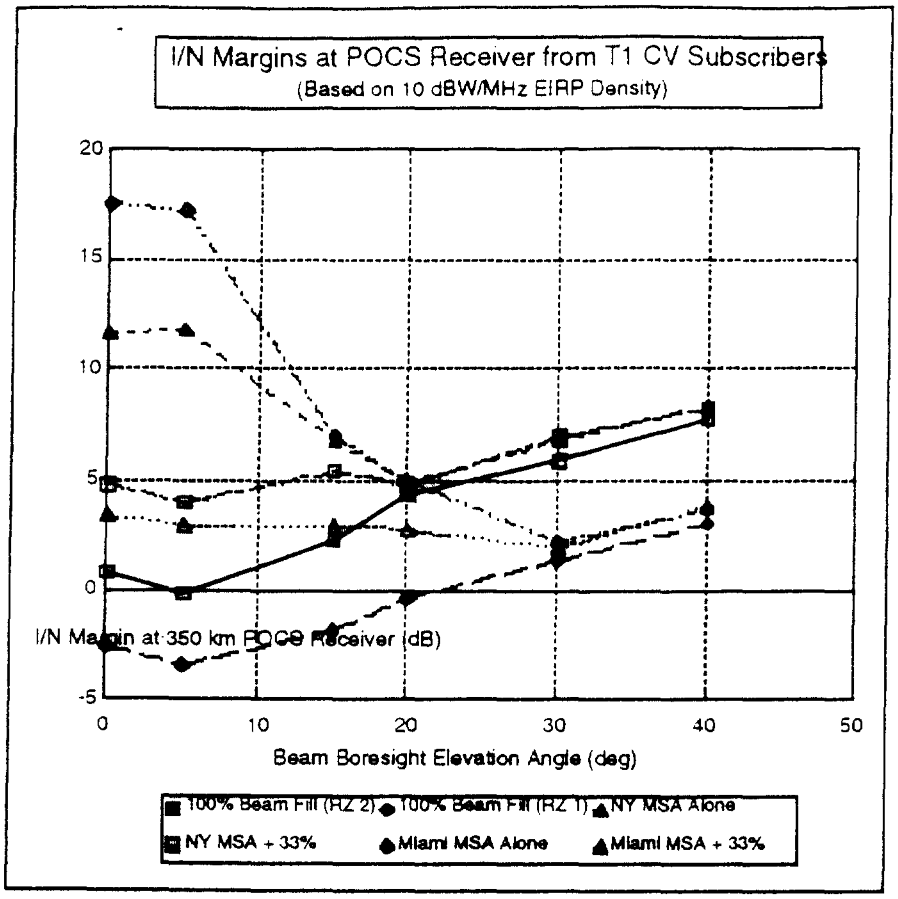

Figure 6-4. CV Subscriber T1 Transmission